A Novel Plug N Play MEMS-Based DNA Microarray

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Abstract

INTRODUCTION-
Microarrays are extensively used in modern biology as tools of multiplexed, high throughput analysis to study thousands of genes and their expression inside cells at once [1]. The basic principle of a microarray is quantitative detection of fluorophore tagged DNA. Use of this method results in microarray experiments being expensive and complex due to fragile and costly fluorophores and instrumentation required to analyse them. Previously, MEMS based DNA sensors have been implemented [2,3], though at a small scale, sensing less than 10 DNA sequences. These sensors suffer from poor signal to noise ratio, cantilever to cantilever variation and impractical scaling of sensing techniques. In this report, we analyse and propose solutions to such problems and also propose a novel DNA chip of scale comparable to microarrays that does fluorophore free detection and also design circuitry to directly interface it to a computer, bypassing need of additional analysis instruments (Figure1).

USE OF COMSOL® software:
We used COMSOL® software to design and simulate a piezoelectric cantilever which forms a single unit of the MEMS DNA microarray, using piezoelectric devices and electromechanics physics. The effects of the local environment were modeled using suitable materials and damping. Stationary analysis was done to check effect of bias, dual parametric sweep of the cantilever dimensions was done to optimize size for lowest variation in natural frequency due to fabrication defects. Eigenfrequency analysis was done to obtain resonant frequency and time dependent study was used to obtain a time varying voltage generated across the piezoelectric layer. In future, we'd use the heat transfer and structural mechanics modules to simulate on-chip heaters for temperature control required during the experiment.

RESULTS-
Our sensor works on the principle of shift of resonant frequency of a cantilever due to change in its mass, a method which provides intrinsic noise immunity [4]. Results are shown in Figure2. Briefly, a damped pre-stressed cantilever was modeled, resonant frequency and displacement of the beam at that frequency were calculated. Length and breadth of cantilever were varied to find region of least variation in natural frequency, to reduce effect of fabrication defects. The electronic circuit includes signal amplification, input noise rejection, band pass filter based noise reduction and digitization. A novel method to sense DNA on a MEMS chip, based on strand displacement [5] has been shown in Figure3. In future, time varying voltage generated across the piezoelectric layer would

be obtained, mathematical analysis of errors due to fabrication defects and variation in DNA length would be done, solutions would be proposed and simulated in COMSOL® software and on chip heaters would be implemented. Complete circuitry for interfacing an array of cantilevers to a digital device will also be implemented.

CONCLUSIONS-
Through this report, we have aimed to implement a novel MEMS DNA microarray that can directly produce electrical signals readable by a computer. This has the potential to drastically bring down the cost and effort required for microarray experiments hence making them accessible to a broader group of scientists.

Reference

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